ac/dc difference, one may set the ac current to the value compared to a dc current by using the basic thermal converter structure. If the reactance errors in the output resistor are zero, then the voltage drop across the output resistor on ac should be the same as the voltage drop on dc. It should be remembered that MFI-μpots are rms transfer devices. The MFI-μpots provided herein are particularly suitable for low voltage, low frequency standards. By the provision of a plurality of resistors of different values with appropriate contact pads, the user is afforded the selectivity of a multi-range, highly compact, rugged, precise MFI-μpot.

In terms of their overall structure, the principal difference between an MJTC and a MFI-μpot is the addition in the latter of selected resistor provided in series with the heater element. Consideration must be given to the so-called "skin effect" which occurs when high frequency ac flows through a conductor. It is well known that alternating current tends to flow along the outer surfaces of the conductor instead of the inner bulk thereof. This skin effect is frequency dependent, so that the effective electrical resistance is different with ac than it is with dc. Therefore, if one employs low resistance conductors, like the output resistors on the MFI-μpots, the skin effect becomes significant. This is particularly true in the low voltage ranges.

As noted earlier, a key structural difference between MJTCs and MFI-μpots is that the latter include one or more electrical resistors in series with the heater element. Various embodiments of such MFI-μpots are described below.

FIG. 2 is a plan view of a MFI-μpot **900** which comprises a single linear elongate heater element **906** provided with an input contact pad **916** at one end. MFI-μpot **900** also comprises thermopiles **908** and **910** symmetrically disposed with respect to heater element **906**. Electrical contact pads **942**, **944**, **946** and **948** are provided for electrical connection of thermopiles **908** and **910**, as best seen in FIG. **2**. Since **900** is a MFI-μpot, it is provided with two output resistors **911** and **913**, each of a different resistance value, on each side. Each set of differently-valued output resistors **911** and **913** can be electrically accessed by appropriate selection of electrical contact pads **971**, **973**, **975**, **977** or **979**, which are disposed as best seen in FIG. **2**.

FIG. **2** also includes two exemplary outside electrical paths, i.e., thin layers of highly conductive material, **981** and **983** which may be formed as part of the integrated multilayer structure on the upper surface of the dielectric substrate (not shown for simplicity). These electrical paths **981** and **983** may be provided with electrical contact pads **991**, **993**, **995** and **997**, as illustrated in FIG. **2**. Return paths **981**, **983** can be connected to other elements of the micropotentiometer and outside sources using wire bonds on the chip, soldered links on the substrate (if ceramic). The return paths can also be wired to the surrounding metal casing. It should be noted that the return paths do not have to be used at all and other means can be used to complete the heater circuit. The MFI-μpot **900** may thus be made part of an instrument circuit or an external test circuit. The heater element, the thermopiles, the differently-valued output resistors, and the outside electrical paths of the MFI-μpot structure can thus be electrically connected and the individual elements accessed and employed as previously described. A very important consideration is to avoid unnecessary current division on ac-dc difference devices, because ac never divides in the same way as does dc. The reason is that ac depends not just on the pure electrical resistance encountered in its path but on reactance. This reactance, as is well understood, will depend on the various capacitances and inductances which may be present, depending upon the layout of the various elements. One key to minimizing such problems is to have small precisely dimensioned structure and regular geometry. As previously described, and as illustrated in FIG. **2**, with conventional techniques of photolithography and with suitable masks very precisely defined elements can be formed and accurately disposed. With a MFI-μpot structure as illustrated in FIG. **2**, one can select an operational range by receiving the output current, whether ac or dc, from heater element **906** across a selected pair of contact pads **971**, **973**, **975**, **977** or **979**. Depending on which pair of these electrical contact pads is selected, one would have a different set of resistors, and hence a different reactance, being employed. One can, in this manner, obtain a very rugged, precise and multi-range MFI-μpot. Because the various films are very thin, and there are rather severe limitations on the sizes of the electrical resistors **911** and **913**, it is convenient to make the different resistors from different metals having different specific electrical resistivities. Persons of ordinary skill in the art, provided with this teaching, can be expected to create a variety of modifications to the described structures.

In the known types of μpots, the current flows through a thermal heater element along a long wire, which is one of the undesirable aspects eliminated by the multifilm integrated structures described herein. In particular, it should be noted with reference to FIG. **2** that there are only very short current paths between adjacent resistors and heater elements. Furthermore, in conventional μpots, the current flows along the heater wire element to a disc resistor at the end of an enclosure surrounding the μpot. The current then flows through the disc resistor and the outside of the metal enclosure. In such a structure, the voltage drop across the disc resistor is what is used as the output voltage from the μpot. By contrast with such known devices, a MFI-μpot such as **900** has several different types of current return paths and options for readily selecting the current return path depending on exactly which type of application for which the MFI-μpot is to be used, e.g., whether it is wired inside an instrument and generates a small reference voltage or whether it is going to be mounted in some kind of cylindrical can or enclosure and used as a working standard or a primary standard. Although not illustrated in FIG. **2**, additional current paths may be provided and employed in conjunction with those which are illustrated.

FIG. **3** illustrates a somewhat modified form of a MFI-μpot **1000** with other variations in the disposition of output resistors and current paths or MFI-μpot structures according to this invention.

Note that in MFI-μpot **1000**, as in MFI-μpot **900**, only heater **1006** is disposed between the hot junctions of thermopiles **1008** and **1010**. Output resistors **1013**, **1015**, **1017**, **1019** and **1021** may be formed to provide selective resistance values, by appropriate selection of size and/or resistive material as previously described. An assortment of small electrical contact pads **1021**, **1023**, **1025**, **1027**, **1029**, **1031** and **1033** may be readily formed for selective engagement of the various resistances provided. In this manner, a highly versatile multi-range, precise and sturdy MFI-μpot is available for use as a primary or working standard.